The Patent Office

24

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Claims searched: 1 and 14 at least

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): B5A (AD24A, AD24P, AD24S, AF39C, AT14C, AT14W)

Int Cl (Ed.6): B29C 45/02 45/78

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 1414385	(CONTROL...) see page 1 lines 95-99 and page 3 lines 105-116; varying temperature of resin.	1,14 at least
Y	EP 0618057 A1	(FORD...) entire document	1,14 at least
A	EP 0229708 A2	(MICRO...) columns 12,13; figure 10 etc.	1,14 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

a catalyst heater is provided upstream of the mixer.

43. Apparatus as claimed in any one of Claims 40 to 42, wherein means are provided for varying the concentration of the catalyst as it flows towards the mixer.

44. Apparatus for resin transfer moulding substantially as herein described with reference to the accompanying drawings.

45. A method of resin transfer moulding substantially as herein described with reference to the accompanying drawings.

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36. A method as claimed in any one of Claims 28 to 35, wherein the variation in the catalyst composition is a variation in strength/concentration.

37. A method as claimed in any one of Claims 28 to 36, wherein catalysts of different chemical compositions are used.

38. Apparatus for resin transfer moulding comprising a resin feed line through which resin and catalyst can be introduced into a mould, a resin heater associated with the feed line for heating resin passing through the line, means for feeding catalysed resin along the feed line and means for varying the catalyst composition in the catalysed resin.

39. Apparatus as claimed in Claim 38, wherein a plurality of reservoirs, each for containing a different resin/catalyst mixture, are connected to the feed line by means of valves which allow any one reservoir, or a combination of reservoirs, to be in communication with the line at one time.

40. Apparatus as claimed in Claim 38, wherein a resin reservoir is provided at one end of the feed line, a plurality of catalyst reservoirs are connected to the line by means of valves which allow any one, or a combination of the catalyst reservoirs, to be in communication with the line at one time, and a mixer is provided in the line to mix catalyst and resin between the ends of the line.

41. Apparatus as claimed in Claim 40, wherein the resin heater is located upstream of the mixer, and is a microwave heater with a rectangular cavity operating in the TE_{102} mode.

42. Apparatus as claimed in Claim 39 or Claim 40, wherein

varied during the course of resin introduction to the mould.

29. A method as claimed in Claim 28, wherein the pre-heating of the resin before introduction into the mould is carried out using a microwave heater.

30. A method as claimed in Claim 28 or Claim 29, wherein a plurality of catalyst reservoirs are connected to a mixing chamber in the resin feed line, and catalyst can be introduced into the mixing chamber for mixing with the resin from more than one of the reservoirs, in any sequence or in any combination, during the course of resin introduction to the mould.

31. A method as claimed in Claim 28 or Claim 29, wherein the concentration of the catalyst is altered during the course of resin introduction to the mould.

32. A method as claimed in Claim 28 or Claim 29, wherein a plurality of resin reservoirs are provided in each of which the resin is mixed with different catalyst compositions, and resin is drawn from more than one of the reservoirs, in any sequence or in any combination, during the course of resin introduction to the mould.

33. A method as claimed in Claim 30 or Claim 31, wherein the catalyst is mixed with the resin before heating of the resin.

34. A method as claimed in Claim 30 or Claim 31, wherein the catalyst is mixed with the resin after heating of the resin.

35. A method as claimed in Claim 34, wherein the catalyst is heated before mixing with the resin.

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can be introduced into a mould, means for feeding catalysed resin along the feed line and means for varying the catalyst composition in the catalysed resin.

23. Apparatus as claimed in Claim 22, wherein a plurality of reservoirs, each for containing a different resin/catalyst mixture, are connected to the feed line by means of valves which allow any one reservoir, or a combination of reservoirs, to be in communication with the line at one time.

24. Apparatus as claimed in Claim 22, wherein a resin reservoir is provided at one end of the feed line, a plurality of catalyst reservoirs are connected to the line by means of valves which allow any one, or a combination of the catalyst reservoirs, to be in communication with the line at one time, and a mixer is provided in the line to mix catalyst and resin between the ends of the line.

25. Apparatus as claimed in Claim 24, wherein the resin heater is located upstream of the mixer, and is a microwave heater with a rectangular cavity operating in the TE_{102} mode.

26. Apparatus as claimed in Claim 23 or Claim 24, wherein a catalyst heater is provided upstream of the mixer.

27. Apparatus as claimed in any one of Claims 24 to 26, wherein means are provided for varying the concentration of the catalyst as it flows towards the mixer.

28. A method of resin transfer moulding using a settable resin, wherein the resin is heated immediately before it is introduced into the mould, to reduce the resin viscosity, and wherein the catalyst composition in the resin stream is

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15. Apparatus as claimed in Claim 14, wherein the controlling means comprises electronic storage means to store a map of the intended temperature variation over the course of injection, a temperature sensor to monitor the actual resin temperature leaving the microwave heating means and a processor which receives temperature information from the sensor and adjusts the power of the microwave heating means to ensure that the temperature profile during injection follows the stored temperature map.

16. Apparatus as claimed in Claim 15, wherein the stored temperature map is a map of temperature against time.

17. Apparatus as claimed in Claim 15, wherein the stored temperature map is a map of temperature against quantity of resin injected.

18. Apparatus as claimed in any one of Claims 15 to 17, wherein a proportional integral derivative controller is used to adjust the power of the microwave heating.

19. Apparatus as claimed in any one of Claims 14 to 18, wherein a proximity sensor is provided in the injection line, between the heating means and the mould, to detect resin arrival.

20. Apparatus as claimed in any one of Claims 14 to 19, wherein a proximity sensor is provided at a mould vent to detect filling of the mould.

21. Apparatus as claimed in Claim 19 or Claim 20, wherein the sensors are capacitive proximity sensors.

22. Apparatus as claimed in any one of Claims 14 to 21, including a resin feed line through which resin and catalyst

8. A method as claimed in Claim 5, wherein a plurality of resin reservoirs are provided in each of which the resin is mixed with different catalyst compositions, and resin is drawn from more than one of the reservoirs, in any sequence or in any combination, during the course of resin introduction to the mould.

9. A method as claimed in Claim 6 or Claim 7, wherein the catalyst is mixed with the resin before heating of the resin.

10. A method as claimed in Claim 6 or Claim 7, wherein the catalyst is mixed with the resin after heating of the resin.

11. A method as claimed in Claim 10, wherein the catalyst is heated before mixing with the resin.

12. A method as claimed in any one of Claims 5 to 11, wherein the variation in the catalyst composition is a variation in strength/concentration.

13. A method as claimed in any one of Claims 5 to 12, wherein catalysts of different chemical compositions are used.

14. Apparatus for resin transfer moulding, the apparatus comprising a mould, means for heating the mould, a reservoir for containing liquid resin mixed with catalyst at a temperature below the catalyst activation temperature, a pipe through which resin can flow in a continuous stream from the reservoir to the mould, microwave heating means arranged to heat the resin flowing along the pipe, immediately before the resin enters the mould, and means for controlling the heating means to heat the resin to varying temperatures during the course of injection.

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Claims

1. A method of resin transfer moulding in which liquid resin flows in a continuous stream into a mould and is heated by microwave heating to a temperature above the resin storage temperature, immediately before the resin enters the mould, and the temperature to which the resin is heated varies during the course of injection.

2. A method as claimed in Claim 1, wherein the course of injection is monitored by time.

3. A method as claimed in Claim 1, wherein the course of injection is monitored by monitoring the quantity of resin injected to the mould.

4. A method as claimed in any preceding claim, wherein the temperature inside the mould is monitored and the temperature to which the resin is heated is varied in accordance with the temperature inside the mould.

5. A method as claimed in any preceding claim, wherein a catalyst introduced into the resin has its composition varied during the course of resin introduction.

6. A method as claimed in Claim 5, wherein a plurality of catalyst reservoirs are connected to a mixing chamber in the resin feed line, and catalyst can be introduced into the mixing chamber for mixing with the resin from more than one of the reservoirs, in any sequence or in any combination, during the course of resin introduction to the mould.

7. A method as claimed in Claim 5, wherein the concentration of the catalyst is altered during the course of resin introduction to the mould.

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transfer moulding is an intermittent process, ie once a mould has been filled with resin, the resin flow has to stop and wait until the product has been ejected before the flow can be restarted to refill the mould in the next cycle. In order to avoid waste of resin, it is important that the resin does not degrade whilst it is stationary in the feed pipe, and the use of microwave heating which can be switched on only whilst the resin is flowing and which imposes no residual thermal load on the resin can be very effective. In practice the microwave circuit may be switched off a short time period before the end of injection, so that when injection comes to an end, the feed pipe 42 is completely filled with resin which has not been subjected to any heating at all.

The apparatus described can provide very accurate control over the resin in the mould. In many cases (but not all) it may be desirable to achieve cure of the resin at the same moment in time throughout the mould. This is likely to result in a short cycle time, which is the objective of the invention.

the resin reaches the mould edge, it has been heated by contact with the mould and consequently the exothermic peak 84b takes place relatively early in the cycle. As a result, and as is shown clearly by Figure 4, curing takes place much earlier at the remote part of the tool than it does close to the inlet and since the product cannot be ejected until curing is complete, curing takes a considerable period of time.

However in contrast when the resin is pre-heated and the temperature of the injected resin varies during injection, a situation can be produced as shown in Figure 5, where there is very little temperature drop (thermal shock) when the resin enters the mould. The exothermic peaks 84a and 84b are very close together and both peaks 84a and 84b are occurring after a considerably shorter time than in Figure 4. The overall cycle time is then dramatically reduced, both as compared with the prior art shown in Figure 4 and as compared with the cycle time achievable by the invention described in EP 0 618 057.

This results from heating of the resin at the start of injection, in order to reduce the resin viscosity which allows it to flow quickly into the mould, followed by an upward ramping of the resin temperature as injection progresses so that the last resin to enter the mould is at a higher temperature than the initially injected resin. This results in the resin at the edge of the mould and at the injection gate curing at practically the same time. Different temperature profiles will be required for different mould sizes and shapes, and the optimum temperature profile can be determined by empirical means.

It is a particular advantage of microwave heating that it can be switched on or off over very short periods. Resin

Since, in the embodiment shown in Figure 3, the microwave heater 124 is heating the resin in the non-reactive state, a rectangular cavity operating in the TE_{102} mode can be used.

In an alternative embodiment however, the microwave cavity could be located downstream of the mixer 136, thus necessitating a cavity tuned to a different mode, as described in EP 0 618 057.

Figures 4 and 5 are temperature versus time profiles. In Figure 5, which represents the prior art where the incoming resin is unheated, the total cycle time 78 is over 700 seconds, and the injection time 80 is about 220 seconds. In this prior art apparatus, the mould is held at a desired, elevated temperature before any resin is introduced. When the cold resin is introduced, the part of the mould around the resin inlet experiences a "thermal quench", ie the temperature of the mould is caused to fall because of the influence of the incoming cold resin. As the contact time between the resin and the mould increases, so the resin heats up. When the resin reaches a certain temperature level as a result of being heated by the hotter mould walls, an exothermic reaction takes place producing temperature peaks 82. As the reaction continues, the exothermic effect reduces so the temperature decays.

Considering Figure 4, the traces 82a and 82b are produced from temperature sensors located, respectively, close to the resin inlet and close to the mould edge. It will be seen that there is a sharp temperature drop at the resin inlet as cold resin is first introduced. When injection is complete, at the end of period 80, the temperature starts to rise and continues to rise until it reaches an exothermic peaks at 84a. The trace 82b which relates to a temperature sensor located remote from the resin inlet shows that by the time

resin shot which has been injected at a constant (elevated) temperature, it will be necessary to vary the resin chemistry (and therefore kinetics) during the shot in order to promote simultaneous cure across the mould. This is necessary to compensate for the different "age" of the resin.

If catalysts of different reactivity are used, the catalyst peroxides will decompose at different temperatures to spread the energy release more evenly over the temperature range.

Normally, the computer 138 will be used to produce predetermined temperature profiles, both with the resin entering the mould and at the different temperature sensing points 140 within the mould. Because external conditions may vary (for example the ambient temperature is likely to vary), the heating and catalyst admixture may vary from cycle to cycle. In accordance with the temperature signals received by the computer 138, a control module 146 controlling the microwave heater 124 will be operated at a required level. Furthermore, valves 148 controlling catalyst flow into the pump 134 will themselves be controlled by the computer 138 to dispense the required amount of the required catalyst at the required time, to the mixing chamber 136 where mixing takes place with the resin.

In addition to thermocouples to monitor the thermal history of the process, pressure transducers can also be incorporated in the mould walls to provide additional information about the progress of each cycle.

It will therefore be seen that the catalyst type is adjusted or varied on-line, during the course of resin introduction to the mould.

aligned with the rate of flow profile across the flowing stream. The heating can therefore be done in a different cavity from that required when heating catalysed resin, preferably in a rectangular cavity using a TE_{102} mode.

In order to vary the catalyst composition in the resin, catalyst at different concentration levels is stored in four separate catalyst reservoirs 126, 128, 130 and 132. The catalyst is pumped from one or more of these reservoirs by a catalyst pump 134 to a mixing chamber 136 in the feed line 118. The catalyst can be heated by a heater 137 before entering the mixer 136. The heater 136 can bring the temperature of the catalyst up to the same temperature as that of the resin leaving the resin heater 124, so that a temperature equilibrium is established prior to mixing.

The arrangement shown is all controlled by a computer 138, and the operation of the system will now be described.

A number of temperature sensing thermocouples 140 are built into the mould and are connected by signal lines 142 to the computer, to report on in-mould temperatures. A thermocouple 144 senses the temperature of the resin entering the mould and will report this also to the computer 138.

Depending upon the thermal history of the resin at different points within the mould, the catalyst type(s) which is (are) mixed with the resin will be varied to produce the desired sequence of cure. For example, in order to minimise the overall cycle time, it may be desirable to force the resin to cure at all points simultaneously, irrespective of the mould fill time. The information necessary to control the catalyst dosing sequence will be determined from the thermal history inside the mould. For example, in the case of a

adjusts the microwave power in order to maintain the set point temperature. Alternatively, a similar function based on time required to fill the mould may be used to profile the resin set point temperature. The magnetron 50 is switched off after resin is detected at the mould vents, and the injection valve 45 is then closed. The mould is opened after a predetermined dwell time to allow the resin to cure to the stage where the product can be removed from the mould and handled.

The embodiment shown in Figure 3 shares many features with the embodiment of Figure 2, but will be described separately. In Figure 3, a mould 110 has upper and lower mould halves 112 and 114 with a mould cavity 116 enclosed by the two mould halves. The mould is fed with resin through a resin feed line 118, which includes a pump 120. Resin is stored in a reservoir 122 and is pumped from that reservoir by the pump 120 through the feed line 118 into the mould cavity 116, where a reinforcement preform has been placed before the mould was closed. The resin is pumped into the mould cavity 116 to wet out the preform and to fill the cavity. When the cavity is full, resin introduction is stopped and the resin is allowed to set. Setting of the resin will be assisted by a catalyst which will have been mixed with the resin before the resin is introduced into the mould.

In order to reduce the viscosity of the resin, and therefore to enable it to flow freely into the mould cavity and through the preform, the resin is heated in a microwave heater 124 which is located in the feed line 118, upstream of the mould 110. Because this heater 124 is heating uncatalysed resin, there is no risk of the resin setting in the feed line 118 and it is not necessary to ensure that the temperature gradient across the flowing stream of resin is

personal computer (PC) 68 which contains a digital to analog converter to control the magnetron 50 automatically. Detection of resin arrival by the sensor 72 causes the PLC 76 to send a digital signal to the PC 68 which signals the control unit 56 to switch the magnetron 50 ON via a digital channel on the digital/analog converter. A proportional-integral-derivative (PID) controller, based on feedback of the resin temperature derived from the thermocouple 67 and/or based on mass of resin injected as derived from the load cell 70, adjusts the microwave power through the analog portion of the digital/analog converter.

The vent sensors 74 are also linked to the PLC 76. When these sensors sense resin arrival at the vents, the signal which they send to the PLC results in the magnetron being switched off.

In use, the resin injection stage is performed as follows. After the mould has been closed and the mould closing clamps have been applied, the resin reservoir 36 is pressurised, the valves 44 and 45 are opened and resin injection begins. The magnetron 50 is switched ON automatically when resin reaches the sensor 72, to start microwave heating of the resin. The heated resin temperature is monitored by the downstream thermocouple 67 which acts in a feedback loop, thereby maintaining a predetermined resin temperature. This set point temperature may be constant or may be set to follow a predetermined temperature profile over the course of one resin injection cycle. The temperature profile may vary with time or with mass of resin injected. Set point temperatures corresponding to 0kg of resin injected and corresponding to the maximum amount of resin required to fill the mould are determined at the start of injection. The set point temperature between these points is varied according to a mathematical function. The PID controller

applicator 54 in which the waves act on the resin to raise the resin temperature. The magnetron 50 is controlled by a control unit 56. The waveguide includes a water load 58 in a branch of the waveguide 52, and a circulator 60 allows forward transmission of microwaves along the waveguide. Tuning screws 62 in the waveguide can be screwed in or out to alter the shape of the electromagnetic field within the waveguide. The waveguide 52 and the tuning screws 62 are set up so that microwaves produced by the magnetron 50 are directed entirely to the applicator 54. Microwave energy will be absorbed by the resin in the pipe 42, but some of the microwave energy will not be absorbed and will be reflected. The circulator 60 will direct the reflected energy into the water load 58 through which water at a known flow rate passes. By monitoring the temperature rise of the water in the water load 58, and by knowing the quantity of microwave energy produced by the magnetron 50 it is possible to obtain a result relating to the quantity of energy or power absorbed by the resin. Further details of the microwave applicator, and of the way in which the applicator uses a cylindrical cavity and is operated is operated in the TM_{020} mode to align the temperature profile across the flowing stream of resin with the flow rate profile are to be found in our European Patent Specification 0 618 057.

In order to be able to control the system, thermocouples 64 monitor the water temperature and thermocouples 66 and 67 monitor the resin temperature. An injection line capacitive proximity sensor 72 is provided to detect resin arrival at the mould, and vent capacitive proximity sensors 74 are provided at the mould vents.

The signals from the thermocouples and from the sensors are directed to a programmable logic controller (PLC) 76 which acts as a switching unit. The PLC 76 is interfaced with a

A final stage in the process is the removal of flash 32 from the edges of the product 30. The present invention is particularly concerned with the stage of injecting the resin which stage is indicated by the reference numeral 34 in Figure 1.

Figure 2 shows the resin handling equipment by means of which the resin is introduced into the mould 22, 24.

Resin mixed with catalyst is stored in a reservoir 36 beneath an air space 38. The reservoir 36 is suspended from a load cell 70 and is replenished through a resin inlet 40. When resin is required at the mould 22, 24 it is fed in the direction of the mould along a flow pipe 42. To replenish the reservoir 36, the valve 44 is closed, the valve 46 is opened and air is pumped out of the space 38 to draw resin into the reservoir through the inlet 40. To pump resin to the mould 22,24, the valve 46 is closed, the valve 44 is opened and the space 38 is pressurised to force resin along the pipe 42. Monitoring the reading on the load cell 70 during injection gives a reading of resin mass flow rate into the mould 22, 24.

The catalysed resin is maintained in the reservoir 36 at a temperature significantly below the catalyst activation temperature so that a reservoir of catalysed resin can be maintained in a usable condition for an extended period of time.

When resin is fed to the mould 22, 24 it flows along the pipe 42 to a microwave heating unit 48 where the temperature of the resin is raised immediately before the resin flows into the mould cavity. The microwave heating unit 48 comprises a magnetron 50 in which the microwaves are generated, a waveguide 52 along which the waves pass and an

of resin transfer moulding apparatus in accordance with the invention; and

Figures 4 and 5 are graphs showing resin temperature against time for, respectively, a constant resin injection temperature and a variable resin injection temperature in accordance with the invention.

Figure 1 illustrates a process where a product 30 is made by resin transfer moulding. A reinforcing mat is first made into a preform and is then placed into a mould into which resin is introduced to produce the product. Figure 1 shows on the left hand side the preparation of the preform and on the right hand side the moulding process itself. As a first stage in the preparation of the preform, a mat 10 is heated in a heater 12 to soften a thermoplastic binding agent so that the mat can be shaped. The mat may be made up from a single type of fibrous reinforcement (e.g. glass fibres, carbon fibres, Kevlar [Registered Trade Mark]) coated with a binding agent and these fibres can be combined in any suitable way in accordance with the demand which will eventually be made on the final product.

The mat is then shaped in a tool 14 which, when closed, cools the mat to solidify the binding agent thus retaining the desired shape. The mat is trimmed at 20 to form a preform 18 which is then placed in the bottom half 22 of a mould. The mould has a top half 24 with an inlet 26 for resin, the flow of which is controlled by a valve 28. Once the preform is in position the mould halves 22, 24 are closed and resin is injected through the inlet 26 to fill the mould cavity and to wet-out the preform 18 thoroughly. Once the mould has been filled with resin, it is left for sufficient length of time for the resin to cure, and the mould is then opened so that the product 30 can be ejected.

line at one time. Alternatively, a resin reservoir can be provided at one end of the feed line, with a plurality of catalyst reservoirs being connected to the line by means of valves which allow any one, or a combination of the catalyst reservoirs, to be in communication with the line at one time. A mixer is then provided in the line to mix catalyst and resin between the ends of the line.

The resin heater can be located upstream of the mixer, and can be a microwave heater with a rectangular cavity operating in the TE_{102} mode.

Where catalyst is mixed with resin in the feed line, there may be an additional heater to heat the catalyst before it is mixed with the resin, so that catalyst and resin are at the same temperature when they are mixed.

Where it is desired to vary the concentration of the catalyst during resin injection, the catalyst may be continuously diluted with a suitable solvent (eg styrene) from a reservoir connected to the catalyst feed line through a mixing valve.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view illustrating a conventional resin transfer moulding process;

Figure 2 schematically illustrates a first embodiment of resin transfer moulding apparatus in accordance with the invention;

Figure 3 schematically illustrates a second embodiment

a mixing chamber in the resin feed line, with the mixing chamber being located between the resin heater and the mould.

Where catalyst is mixed with resin in the feed line, the catalyst may itself be heated before it is mixed with the resin, so that catalyst and resin are at the same temperature when they are mixed.

Alternatively, two or more resin reservoirs in which the resin is mixed with different catalyst compositions can be maintained, and resin can be drawn from one or other of the reservoirs during the course of resin introduction.

In another alternative, there may be a single catalyst reservoir, and provision may be made for varying the catalyst concentration during the course of resin introduction.

The variation in the catalyst composition may be a variation in strength/concentration, or there may be catalysts of different chemical compositions or different reactivity.

The invention therefore also provides apparatus for resin transfer moulding comprising a resin feed line through which resin and catalyst can be introduced into a mould, a resin heater associated with the feed line for heating resin passing through the line, means for feeding catalysed resin along the feed line and means for varying the catalyst composition in the catalysed resin.

A plurality of reservoirs, each for containing a different resin/catalyst mixture, can be connected to the feed line by means of valves which allow any one reservoir, or a combination of reservoirs, to be in communication with the

by monitoring the quantity of resin injected to the mould, or by monitoring the temperature within the mould.

The controlling means preferably comprises electronic storage means to store a mathematical function representing the intended temperature variation over the course of injection, a temperature sensor to monitor the actual resin temperature leaving the microwave heating means and a processor which receives temperature information from the sensor and adjusts the power of the microwave heating means to ensure that the temperature profile during injection follows the stored temperature map. The stored temperature map may be a map of temperature against time or a map of temperature against quantity of resin injected.

A proportional integral derivative controller can be used to adjust the power of the microwave heating.

A proximity sensor can be provided in the injection line, between the heating means and the mould, to detect resin arrival, and another proximity sensor or sensors can be provided at a mould vent to detect filling of the mould. The sensors can be capacitive proximity sensors.

In addition, or alternatively, to the temperature control steps set out above, the cycle time can be speeded up by heating the resin immediately before it is introduced into the mould, to reduce the resin viscosity, and by varying the catalyst composition in the resin stream during the course of resin introduction to the mould.

The catalyst (sometimes also called an initiator) may be mixed with the resin, either before or after heating of the resin. In a preferred embodiment, there are a plurality of catalyst reservoirs which can be connected sequentially to

has had catalyst mixed with it, it is important to ensure that the energy in the microwave cavity is properly distributed across the flowing resin, to prevent premature cure of the resin at the edges of the cavity. When the resin is mixed with catalyst prior to heating it is preferred to adopt the features described in our European Patent Application 0 618 057, and in particular to use a TM_{020} cavity.

There are two time periods to be considered in respect of the process after resin begins to enter the mould. Firstly there is the impregnation time, i.e. the time required for the resin to flow from the resin inlet to all parts of the mould and throughout the reinforcement whilst ensuring thorough wetting-out of the reinforcement. To reduce this impregnation time the viscosity of the resin should be as low as possible. One method of achieving this is to heat the resin, but not to heat it so far that cure takes place before the resin has flowed to all parts of the mould.

Secondly it is necessary to consider the time from entry of the resin into the mould to completion of resin cure. For the thermoset resins used in resin transfer moulding, curing takes place by raising the temperature of the resin. The higher the temperature is raised the faster the cure.

In order to reduce the cure time as far as possible, it is necessary to heat the mould. In order to reduce the injection time the resin is heated before it is introduced into the mould. The heating of both parts of the apparatus must however be done under fully controlled conditions to avoid premature cure of the resin and to prevent waste of resin between cycles.

The course of injection can be monitored either by time, or

It is possible to produce quite complex moulded products using this process. The reinforcement can be formed to provide necessary strength in areas where strength is required, because the reinforcement can be "designed" independently of the moulding process. However for RTM to become a viable process for use in mass production of articles, it is desirable to minimise the cycle time, i.e. the time from ejection of one product from the mould to ejection of the following product from the same mould.

According to the present invention, there is provided apparatus for resin transfer moulding, the apparatus comprising a mould, means for heating the mould, a reservoir for containing liquid resin, a pipe through which resin can flow in a continuous stream from the reservoir to the mould, microwave heating means arranged to heat the resin flowing along the pipe, immediately before the resin enters the mould, and means for controlling the heating means to heat the resin to varying temperatures during the course of each injection cycle.

The invention also provides a method of resin transfer moulding in which liquid resin flows in a continuous stream into a mould and is heated by microwave radiation to a temperature above the resin storage temperature immediately before the resin enters the mould, and the temperature to which the resin is heated varies during the course of each injection cycle.

The resin may be mixed with a catalyst either before or after the resin passes through the microwave heating means. If the heating takes place when the resin is uncatalysed, the temperature gradient across the cross section of the flowing body of resin is not critical. However if the resin

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RESIN TRANSFER MOULDING

This invention relates to resin transfer moulding and in particular to an apparatus for resin transfer moulding as well as to a method of resin transfer moulding.

In resin transfer moulding (RTM) a fibrous reinforcement is placed in a mould cavity and the mould is closed. Liquid resin is then injected into the mould cavity so that it flows through the reinforcement to wet the reinforcement thoroughly. The resin is then allowed to cure and after cure the moulded product is ejected from the mould.

Curing of the resin is highly temperature dependent, and takes place at temperatures only slightly above ambient temperatures. For example one typical polyester resin system consists of a base resin sold under the designation CV 6345 by Cray Valley Total Chemie and 2% of the catalyst Perkadox 16 sold by AKZO. At room temperature, this system would last for about 4 hours before curing, whereas at 60°C it would cure in about 6 minutes. In using this system, it would be the intention to raise the mould temperature to 60°C to cure the resin, ie by about 40°C from a typical ambient temperature of 20°C. In another example, the same base resin is used with 1% of TBPEH (sold by AKZO) as catalyst. At room temperature this system would last for about 10 hours before curing, whereas at 70°C it would cure in about 16 minutes. Since the ambient temperature may vary between about 0°C and 30°C from day to day, and during each day, changes in ambient conditions can significantly affect the curing time of the resin and it is therefore necessary to ensure that corrections are made to the moulding conditions to compensate for changes in ambient conditions which would otherwise make the process inconsistent from one cycle to the next.

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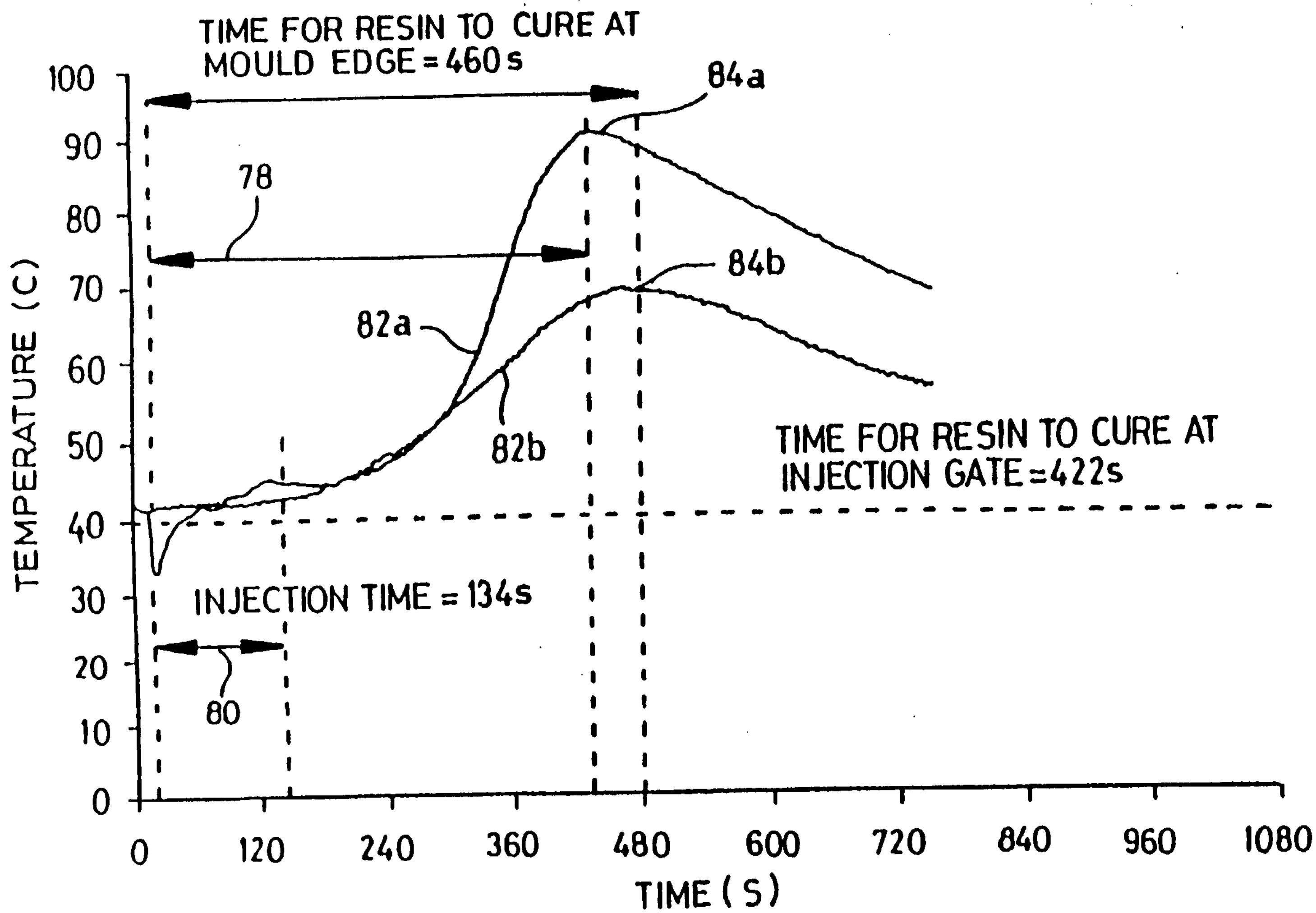
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78
84b
82a
82b
TIME FOR RESIN TO CURE AT
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80
TEMPERATURE (C)
100
90
80
70
60
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960
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TIME (S)

Fig. 5

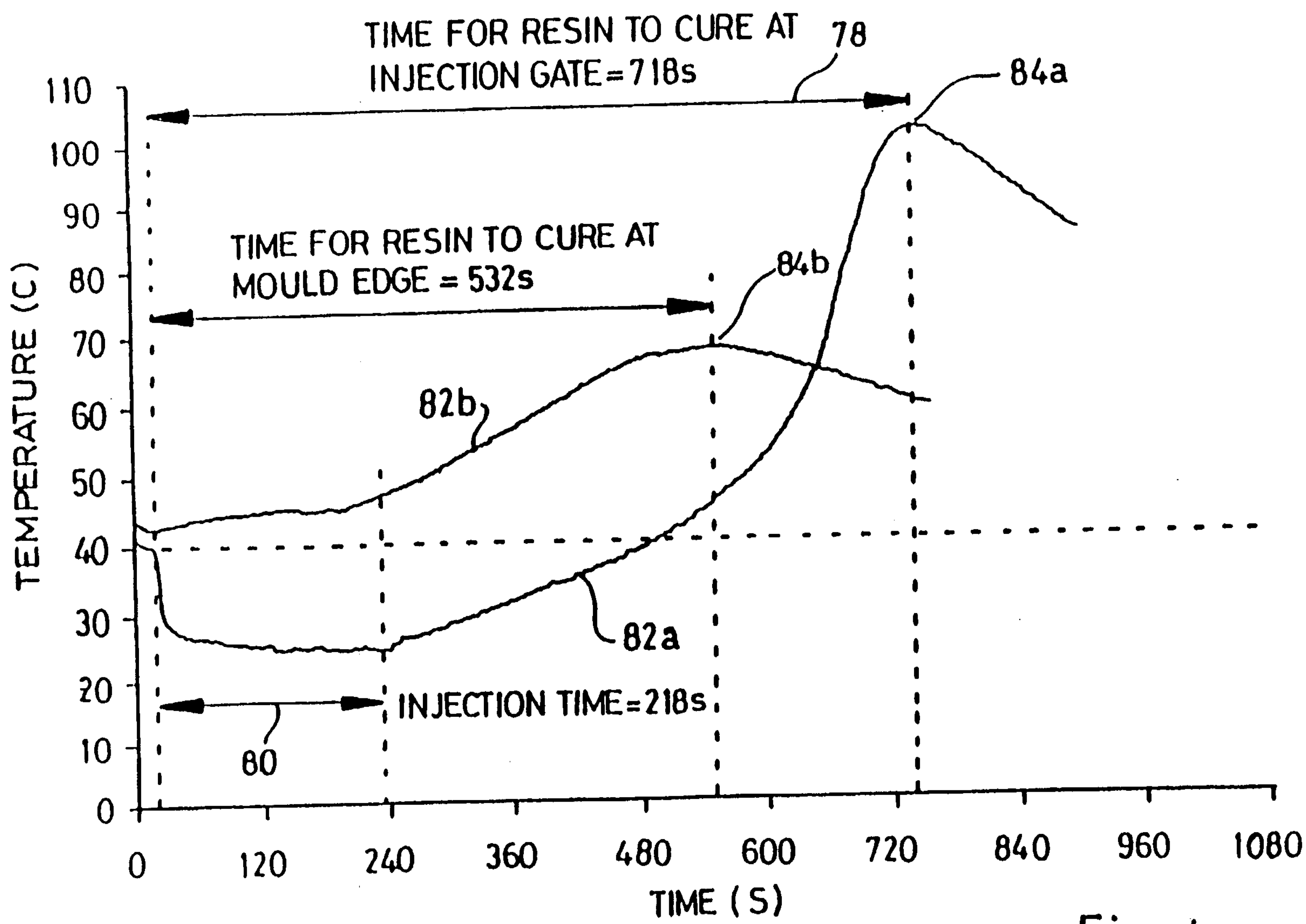
TIME FOR RESIN TO CURE AT
INJECTION GATE = 718s
78
84a
TIME FOR RESIN TO CURE AT
MOULD EDGE = 532s
84b
82b
82a
INJECTION TIME = 218s
80
TEMPERATURE (C)
110
100
90
80
70
60
50
40
30
20
10
0
0
120
240
360
480
600
720
840
960
1080
TIME (S)

Fig. 4

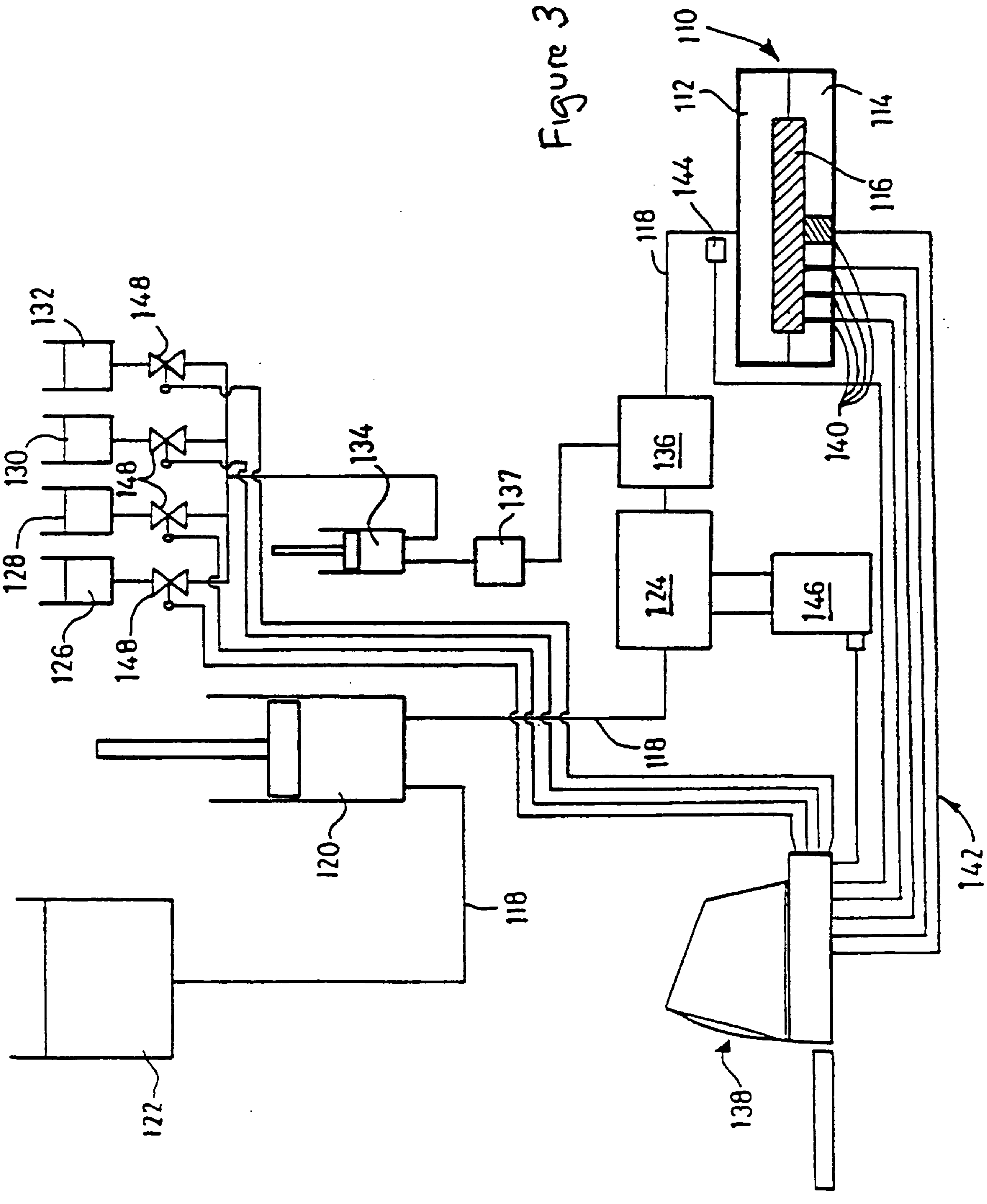
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Figure 3

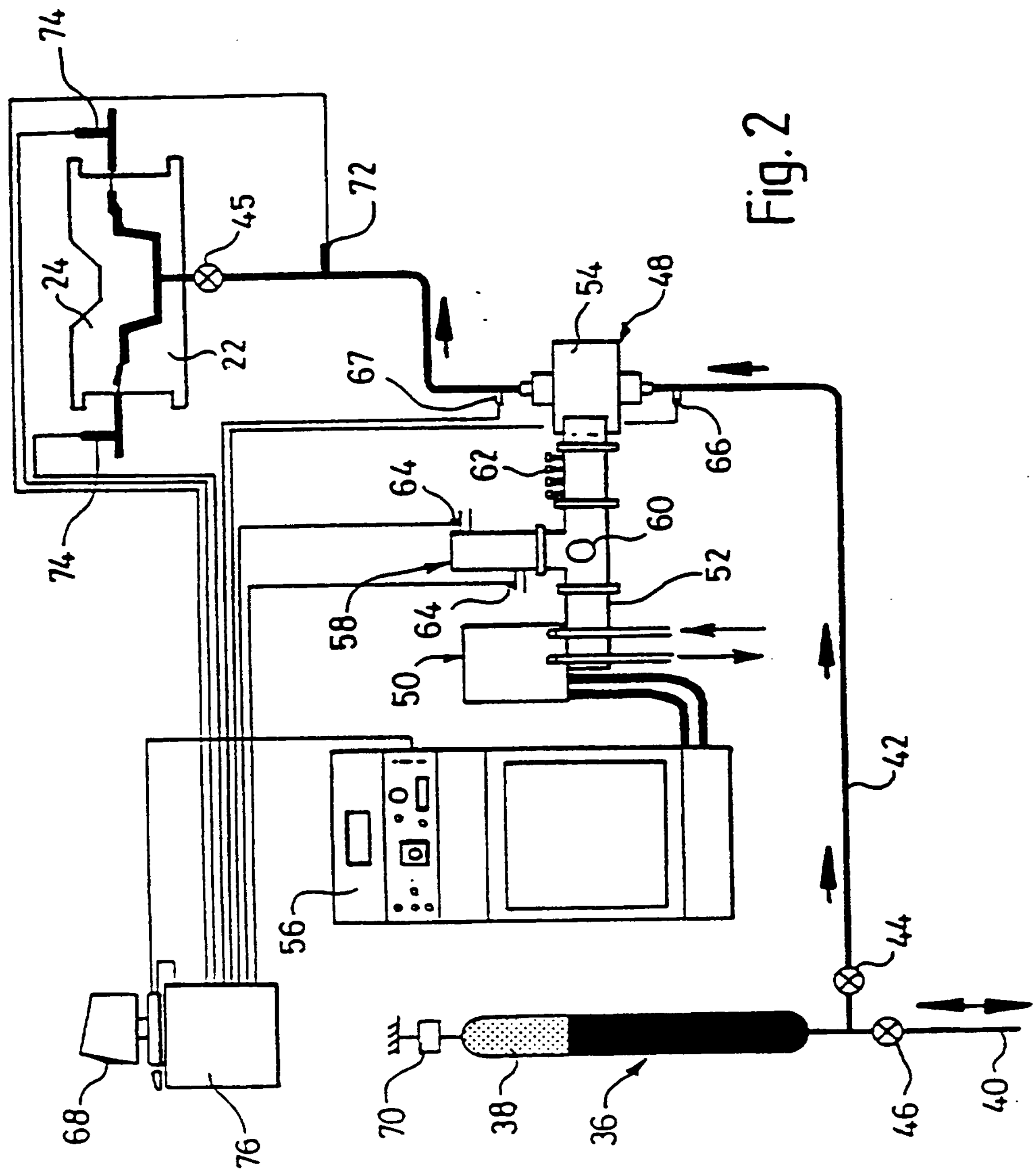
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Fig. 2

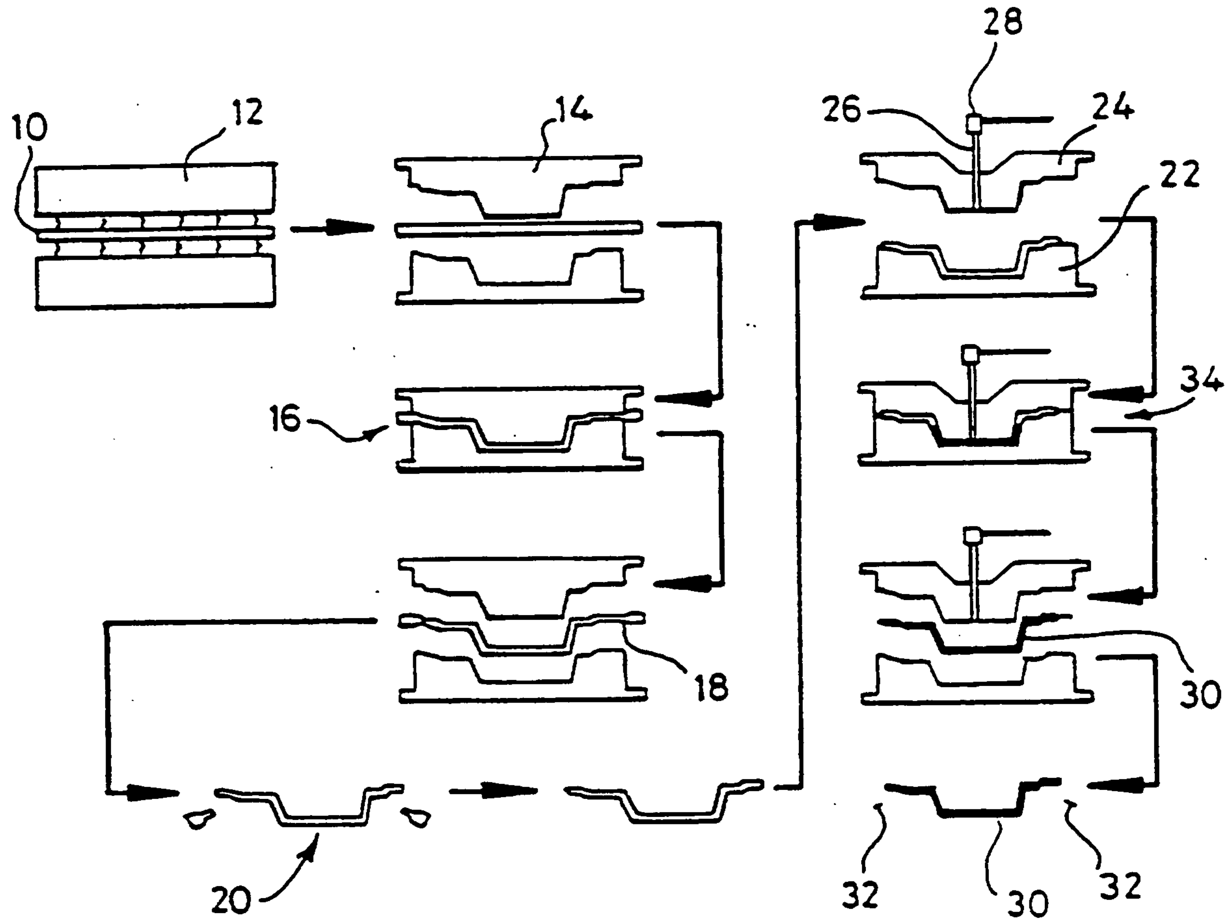

Fig. 1

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B29C 45/78 45/02

(52) UK CL (Edition O)
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GB 1414385 A EP 0618057 A1 EP 0229708 A2

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UK CL (Edition O) B5A AD24A AD24P AD24S AF39C AT14C AT14W
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(54) **Resin transfer moulding with controlled heating of resin**

(57) In a resin transfer moulding, the resin, along a conveying line 42, is heated before it is introduced into the mould 22, 24 to a temperature which is below the temperature at which curing of the resin will begin. As inj ction proceeds, the temperature of the resin being injected is continuously varied through microwave heating unit 48 upstream of the mould 22, 24.

The resin may be catalysed before being heated (see Figure 2) or the resin and the catalyst may be heated separately before being mixed together (see Figure 3). In the latter a plurality of catalyst chambers 126, 128, 130, 132 are connected to a mixing chamber 136. The resin cures inside the mould. The temperature is controlled by a control circuit using sensors 64, 66, 67, 72, 74/140, 144 etc.

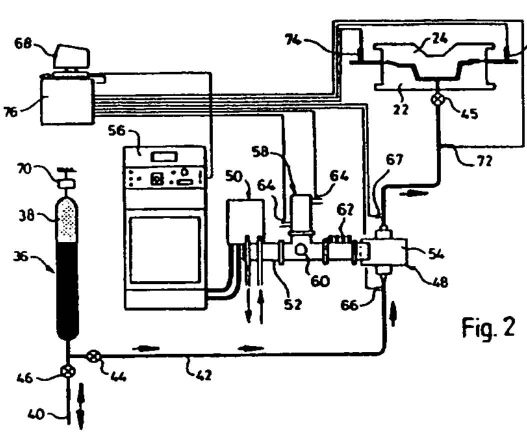

Fig. 2

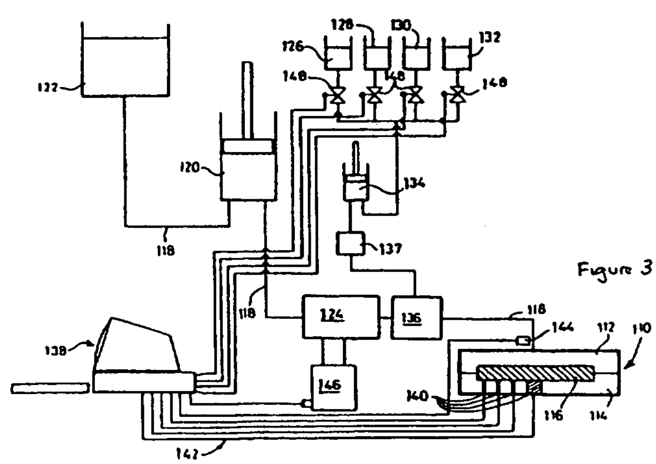

Figure 3

GB 2 301 059 A

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,160,754

1,160,754

Date of Application and filing Complete Specification: 8 Aug., 1966.
No. 35366/66.
Application made in France (No. 46309) on 13 Aug., 1965.
Application made in France (No. 46941) on 14 Feb., 1966.
Complete Specification Published: 6 Aug., 1969.

Index at acceptance: —**B5** A(1R14C1C, 1R100, 2A1, 2D1X, 2E2, 2E3, 3D1A, 3D1C, 3D2, 3D3, 3D4X, 3D12)

International Classification: —**B 29 f 1/00**

COMPLETE SPECIFICATION

Improvements in or relating to Injection Moulding Machines

We, SOCIETE POUR LA TRANSFORMATION DES MATIERES PLASTIQUES STAMP, a joint stock company of French nationality of Nurieux (Ain-France), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The present invention relates to injection moulding machines, as used for the injection moulding of plastics articles. The invention is particularly applicable to the manufacture of bottle racks or crates or other articles of similar dimensions, although it should be understood that the invention is not restricted to the manufacture of any specific type of article.

Taking the example of a bottle crate, it is known to make crates from plastics (especially high density polyethylene). The weight of such a crate is at the present time about 2 Kilogrammes and its dimensions may be for example 450×335×360 millimetres for a crate intended to hold twelve one-litre bottles. The parts on the side opposite to the core (principally stiffening ribs) with which the crates are provided lead to the use of a mould of which the female part carries four detachable components which are themselves enclosed in a shell. Since the article is a fairly deep drawing, and the assembly is quite bulky, it has to be fitted to a high-power press, in spite of the relatively small weight and dimensions of the completed crate.

The known method, which is therefore to make an object of relatively small dimensions on a high-capacity press, is acceptable for manufacture in short runs when the same mould is never left very long on the press. On the other hand, for manufacture in very long runs when the mould remains in place for several years, as for example is usually required in the case of bottle-crates, this leads to a real waste of the capacity of the machine.

The invention aims at eliminating this disadvantaage by providing a machine specially designed for a given manufacture, of which the cost price, of one to make for example bottle-crates, will be very much less than that of a conventional injection moulding assembly.

According to this invention an injection moulding machine comprises a stationary mould part which forms at least part of the configuration of the mould, guiding columns attached directly to the stationary mould part, a movable mould part slidably mounted on the guiding columns, so that the movable part can slide between an inoperative position where it is clear of the stationary mould part and an operative position where it engages with the stationary mould part, a mould closing mechanism supported by the guiding columns for actuating the movable mould part between its operative and inoperative positions, and for pressing the two mould parts together when the movable part is in the operative position, a mould-latching jack, a latching chock movable perpendicularly to the direction of movement of the movable mould part into a position between the latching jack and the movable mould part, when the latter is in the operative position, so that a latching force can be transmitted to the movable mould part from the latching jack through the latching chock, and means for injecting a plastic material into the mould.

It is preferred that the movable mould part should be supported only by the guiding columns. According to another preferred feature of the invention the stationary part of the mould includes elements adapted to form parts of the configuration of the mould, these

elements being mounted for movement on a body of the stationary part in directions transverse to that of the movement of the movable mould part between outer inoperative and inner operative positions, these elements coacting with the body in their operative positions to form one side of the mould configuration.

According to another preferred feature, a latching chock is movable perpedicularly to the direction of movement of the movable mould part, and a short stroke latching jack is provided on the machine, the arrangement being such that the latching chock can be moved into a position between the latching jack and the movable mould part, when the latter is in the operative position, so that a latching force can be transmitted to the movable part from the latching jack through the latching chock.

Preferably the means for injecting plastic material includes a screw conveyor, and there may be a transfer pot and valve means for controlling the flow of material from a reservoir into the mould or the transfer pot. This enables the screw conveyor to turn without interruption and ensures a high uniformity of plastification, which is very important for the good mechanical strength of the crate or other article being produced.

It will be understood that such a machine, in which the latching-jack has only a short stroke, whilst in addition the conveyor feeds the mould at a relatively low pressure, may be made at a much lower cost price than a machine of known type.

It is also preferred to provide two or more plates which together form an outer wall of the mould, these plates being mounted for movement perpendicularly to the movement of the movable part of the mould into and out of their operative positions.

Following a preferred feature of the invention, each of the movable plates of the mould is carried by the stem of a jack, and these jacks may be mounted on a frame which slides on the guiding columns.

The base plate and the movable plates may carry attached plates which allow the model to be changed in an economical way, for example, when it is desired to make the same model of container, but with one version with solid walls and one version with pierced walls.

Several constructions of moulding machines in accordance with the invention will now be described by way of examples only, with reference to the accompanying drawings, in which:—

Figure 1 is a sectional view of a moulding machine when the mould is closed.

Figure 2 is a view similar to Figure 1 at the moment of removing a bottle-crate from the mould,

Figure 3 is a sectional view of another machine when the mould is closed,

Figure 4 is a view similar to Figure 3 at the moment of removing a bottle-crate from the mould,

Figure 5 illustrates another possible variant for feeding the mould,

Figure 6 is a schematic view showing a manufacturing variant for the auger.

The machine shown in Figures 1 and 2 is intended to manufacture bottle-crates A from plastics. Each crate A has ribs 1 around the outside which re-inforce it.

The mould comprises a fixed female part 2 and a sliding male part 3. The inside of the female part 2 is formed by four plates 4 which are carried in slideways, not shown, on a base 5 which forms part of the male part 3. The plates 4 are arranged to slide apart automatically in directions perpendicular to the movement of the male part 3 when the mould is opened to allow the parts of the crate A on the opposite side from the core to be removed from the mould. Guide columns 6 are fixed to and projecting from the fixed part 2 ensure the correct sliding of the base 5 of the male part 3 relatively to the fixed female part 2, the movement being controlled in the conventional way by opening and closing jacks 11. The guide columns 6 constitute the only supports for the base 5.

On one side of the machine there is provided a double-acting jack 7 of which the stem carries a latching chock 8 so that the latter can be moved perpendicularly to the direction of the movement of the male part on the columns 6. This chock brings one of its ends to bear against the rear face of the base 5 when the mould is closed (Figure 1) while its other end is then applied against a piston 9 of a latching jack formed in a fixed plate 10 also supported by the guide columns 6.

Given the considerable wall thicknesses which the crate A must have for reasons of mechanical strength, it is not necessary to inject the plastics material at a high pressure to ensure a satisfactory product. It is enough to have the pressure furnished by an endless-screw conveyor or auger 12 of known type which discharges continuously all the time the machine is operating into a reservoir 13 where the plastics material is stored between two successive injections controlled by the opening of a valve cock 14.

The operation of this machine is as follows:—

At the moment of injection, the force exerted by the piston 9 is applied to the chock 8 and is transmitted to the male part of the mould, of which it ensures the latching (Figure 1). It suffices to open the injection cock 14 for the plastics material to be forced out into the mould. A hydraulic jack (not shown) pulls the housing of the screw conveyor towards the plastics reservoir 13 to maintain

pressure on the plastic material in the reservoir (as described with reference to the arrangement illustrated in Figures 3 and 4).

The fact that the auger 12 turns continuously ensures a great homogeneity of the plastified material, which is favourable to the strength of the finished crate A.

To remove the product from the mould, it suffices to release the pressure on the latching piston 9, then to retract the jack 7 which withdraws the chock 8 transversely in the direction shown by the arrow 15 (Figure 2), before opening the mould in the conventional way by operating the jacks 11. The crate A, ejected by some extractors, then falls completed from the machine.

The mould is then closed again by the opposite movement, then it is latched by extending the jack 7 once more, which replaces the clock 8 in position, and by sending pressure against the piston 9 of the latching jack which acts on the said chock 8.

It will be seen that the latching of the mould may be ensured by a jack of which the piston 9 has a very short stroke in spite of the great length of slide of the male part 3 along the guide columns 6, due to the fact that the crate is a deep drawn article.

Referring now to Figures 3 and 4:

The mould comprises a fixed female part 20 and a slidable male part 3 carried on a base 5. Four mould plates 22, are arranged between the parts 20 and 5 to complete the mould. Contrary to the preceding example however each plate 22 is independent of the base 5. The back of each plate is fixed to the rod 23 of a piston 24 which slides in the cylinder 25 of a double-action jack. The latter is pointed radially, that is to say each one of the four jacks 23—24—25 is directed towards the centre of the mould perpendicular to the corresponding plate 22.

In addition, a frame 49 which carries the four plates 22 and the four jacks 25, 24, is linked to the part 20 by two jacks 26—27—28 fixed to the plate 20. These two jacks allow the displacement of the frame along the four columns 6.

In this arrangement the plastics reservoir 13 has been completed by a transfer-pot system which may or may not be used due to the use of a valve cock 43. As has been described previously, the use of this transfer-pot takes place for the manufacture of plastics parts demanding a relatively high filling pressure.

The operation of the injection in each of the two cases is as follows (Figure 3):

1st) Operation with the transfer-pot.

The auger 12 turns without interruption and discharges continuously thermo-plastic material into the reservoir 13. The speed of the screw of the auger 12 is regulable, which allows the filling output of thermoplastic material into the reservoir 13 to be regulated.

As shown in Figure 3, a piston 39 is provided within the reservoir 13 and a hollow connecting rod joins the cylinder of the auger 12 to the piston 39. The rod of a hydraulic rein 40 is fixed to the cylinder of the auger 12, so that the rein resists movement of the cylinder away from the reservoir.

The filling of the reservoir 13 causes the piston 39 fixed to auger 12 to withdraw. The withdrawal of the piston 39 is braked by the action of a construction in the channel which carries the hydraulic fluid feeding the annular part of the rein 40. This has the object of compressing the material in the reservoir as it is filled by the auger 12.

To commence at the moment when an injection has just taken place, the cock 38 is then closed, the cocks 43 and 37 are open, and the injection piston 30 is at the end of its travel.

The cock 37 is closed, the cock 43 left open, and the cock 38 opened. Pressure is sent into the annular part of the hydraulic rein 40. The piston 39 then pushes the plastic material into the pot 29. When the pot 29 is filled with the quantity of material just necessary to fill the mould, the cock 38 is closed. The pressure in the rein 40 is removed, and the auger, which has not stopped during all this time, fills once more the reservoir 13 which has been emptied to fill the pot 29.

The pot 29 is then ready to ensure an injection into the mould. When this injection is to take place, that is to say when the previously made part is cooled, the mould has been opened, and the part has been ejected from the mould, then the latter re-closed, the cock 37 is opened and the material contained in the transfer-pot is pushed by means of the piston 30 fixed to a hydraulic jack 32—33. In certain cases it is advantageous to put the jack 32—33 under pressure first, in order to compress the material in the pot 29, the cock 37 being closed. Thus a pre-compression of the material is ensured, so that it fills the mould more rapidly when the cock 37 is opened.

2) Operation without transfer-pot

The cock 43 is closed and the cock 38 left open. The cock 37 then acts as does the cock 14 in the example shown in Figures 1 and 2 and the injection is therefore identical with that described previously.

It is to be noted equally that the auger 12 may be fitted with a de-gassing system, as is conventionally found on certain augers. This allows a plastic material to be obtained free from all gas, which is useful for the injection of certain thermoplastic materials.

The operations of opening and closing the mould are as follows (Figures 3 and 4):

1) Opening the mould.

The injection has been made and the part is cooled in the mould.

The following operations are carried out successively

—The jack 9 is contracted;

—The jack 7 is contracted, which withdraws the chock 8 as is shown by the arrow 15 of Figure 2. So that the withdrawal of the chock 8 shall be made without rubbing against the rear face of the plate 5, the face 50 of the chock 8 which bears against the rear face of the plate 5 is furnished with a certain relief angle. The rear face 51 of the plate 5 is formed with the same relief angle;

—The jacks 11, 23—24—25—27—28 are contracted simultaneously. This operation withdraws the male part 3 whilst stripping the plastics part of its four plates 22 in which it is captive. The plastics part is then lightly detached from the male part 3. The complete stripping of the male part is ensured by a stripping-plate 47 as is conventional in certain injection moulds. The part then falls and is carried out of the machine by a conveyor belt on to which it has fallen.

2) Closing of the mould.

This operates in the following way.

—The jacks 24—25—26 bring the four plates together again.

—The two jacks 27—28 draw the frame 49 in such a way that the ends of the four plates 22 come to engage in corresponding sloping parts of the plate 20.

—The jack 11 advances the male 3.

—The chock 8 descends.

—The jack 9 ensures the closing pressure.

The injection may then be made.

Now, regarding this injection, in the case of certain parts, as for example handling containers with thin walls, it may be necessary to injection at several points. In this case the arrangement as shown in Figure 5 is adopted.

If it is desired, for example, to make an injection at three points, a circuit of reinforced tubes fitted with electric heating resistors is used, such as 50. The branches 71 then penetrate as deeply as possible into the plate 20. The injection channels 52 which remain after the part is moulded (commonly called "plugs") are then very short and there is no need to cut them off after the part is removed from the mould. This characteristic is particularly useful in the case of the invention which seeks to produce parts in an automatic cycle, without manual intervention.

To avoid too great a thickness for the plate 20 it is preferred to attach a plate 53 of fairly great thickness which strengthens the plate 20 to which it is fixed by means of suitable blocks 54 arranged around the pipework 50.

It will be understood that the operating cycle which has just been described may be carried out entirely automatically by means of a judicious synchronisation of the different fixed or m vable jacks of the installation.

The plastics reservoir which has just been described has the advantage of continuous agitation of the plastics material, which is essential in the plastification of the material. On the other hand it has one disadvantage; it obliges the auger to be displaced parallel to its own longitudinal axis and this is a relatively complicated construction. This disadvantage may be mitigated by making the assembly as is described below and shown in Figure 6.

The auger 61 is fixed and discharges continously into an auxiliary reservoir 62, likewise fixed. The difficulty is to avoid any setting of plastics material. For this, it is necessary that the head of a piston 63 comes into contact with the bottom 70 of the cylinder of the plastics reservoir at each charge of the transfer-pot 64.

This is arrived at in the following way:

To commence from the moment when an injection has just taken place. The injection piston 65 is at the end of its travel in the transfer-pot 64. The cock 66 is closed, the cock 67 is open. The auxiliary reservoir 62 contains a certain quantity of plastics material.

The cycle is as follows:

The cock 67 is closed and the cock 66 opened. Pressure is put into the jack 68. The piston 63 advances, forcing the plastics material from the reservoir 62 into the transfer-pot 64. Since, as will be seen later, the quantity of material contained in the reservoir 62 is smaller than the quantity with which it is desired to charge the transfer-pot to ensure the complete filling of the mould, the head of the piston 63 comes into contact with the bottom 70 of the cylinder of the pressure reservoir 62 (shown by the broken line in the drawing). The auger, which has never stopped, then continues to fill the transfer-pot with plastics material. When the transfer-pot is charged with exactly the quantity of material necessary completely to fill the mould, the cock 66 is closed. The auger then again discharges into the auxiliary reservoir 62, raising its piston 63.

When it is desired to make the injection, it suffices to open the cock 67 and to put pressure into the hydraulic jack 69. The head of the piston 65 then comes to the end of its travel in the cylinder of the transfer-pot 64.

The machine is then in the starting condition, and the cycle re-commences.

For all this, and in particular so that the head of the piston 63 shall at each cycle come into contact with the bottom 70 of the cylinder of the reservoir 62, it is essential that the output of plastics material from the auger be regulated so that the quantity of

plastic material which it discharges during the time (t) of duration of a complete cycle (that is to say, closing of the mould, injection, cooling of the part, opening of the mould, ejection of the part, closing of the mould) corresponds exactly with the weight of the part injected. This result is easily arrived at by furnishing the drive system of the screw with a device for regulating the speed of the said screw.

In Figure 6 there is illustrated diagrammatically a drive means comprising an electric motor and a belt drive working between cone pulleys, so that the speed of the auger can be regulated by adjusting the belt drive.

WHAT WE CLAIM IS:—

1. An injection moulding machine comprising a stationary mould part which forms at least part of the configuration of the mould, guiding columns attached directly to the stationary mould part, a movable mould part slidably mounted on the guiding columns, so that the movable mould part can slide between an inoperative position where it is clear of the stationary mould part and an operative position where it engages with the stationary mould part, a mould closing mechanism supported by the guiding columns for actuating the movable mould part between its operative and inoperative positions, and for pressing the two mould parts together when the movable part is in the operative position, a mould-latching jack, a latching chock movable perpendicularly to the direction of movement of the movable mould part into a position between the latching jack and the movable mould part, when the latter is in the operative position, so that a latching force can be transmitted to the movable mould part from the latching jack through the latching chock, and means for injecting a plastic material into the mould.

2. An injection moulding machine as claimed in Claim 1, in which the movable part is supported only by the guiding columns.

3. An injection moulding machine as claimed in either of Claims 1 and 2, in which the stationary part of the mould includes elements adapted to form parts of the configuration of the mould, these elements being mounted for movement on a body of the stationary part in directions transverse to that of the movement of the movable mould part between outer inoperative and inner operative positions, these elements coacting with the body in their operative positions to form one side of the mould configuration.

4. An injection moulding machine as claimed in any one of Claims 1 to 3, in which the movement of the movable mould part is effected by a ram and cylinder device.

5. An injection moulding machine as claimed in any one of Claims 1 to 4, in which the latching jack is a ram-and-cylinder device.

6. An injection moulding machine as claimed in any one of Claims 1 to 5, in which the movable part of the mould carries two or more plates slidable on that part in directions perpendicular to the movement of the movable part, the plates being adapted to form parts of the mould configuration when in their contracted positions.

7. An injection moulding machine as claimed in any one of Claims 1 to 6, in which the means for injecting plastic material includes a screw conveyor.

8. An injection moulding machine as claimed in any one of Claims 1 to 7, in which there is a transfer-pot and valve means for controlling the flow of material from a reservoir into the mould or the transfer pot.

9. An injection moulding machine as claimed in Claim 8, in which a power operated piston is provided in the transfer pot for forcing material out of the pot into the mould.

10. An injection moulding machine as claimed in Claim 7, and in Claim 8 or Claim 9, in which a piston is provided within the reservoir there being a rod extending from this piston and a hydraulic rein connected to the rod to resist outward movement of the piston as a result of material being forced into the reservoir by the screw conveyor so that the hydraulic rein applies compressive force *via* the piston to the material in the reservoir.

11. An injection moulding machine as claimed in any one of Claims 8 to 10, in which there is a passage between the reservoir and the mould and this passage divides into two or more branches leading into the mould at spaced positions.

12. An injection moulding machine as claimed in any one of Claims 8 to 11, in which there is an auxiliary reservoir in communication with the reservoir, and piston means within the auxiliary reservoir for discharging a quantity of plastic material less than that required to fill the mould from the auxiliary reservoir at each operation of the said piston means.

13. An injection moulding machine as claimed in Claim 1, constructed and arranged substantially as herein described with reference to Figures 1 and 2 of the accompanying drawings.

14. An injection moulding machine as claimed in Claim 1, constructed and arranged substantially as herein described with reference to Figures 3 and 4 of the accompanying drawings.

15. An injection moulding machine as claimed in Claim 1, constructed and arranged substantially as herein described with reference to Figures 3, 4 and 5 of the accompanying drawings.

16. An injection moulding machine as claimed in Claim 1, constructed and arranged substantially as herein described with reference to Figures 3 and 4 as modified by Figure 6 of the accompanying drawings.

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15 Clare Road,
Halifax,
Yorkshire,
Agents for the Applicants.

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1160754 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

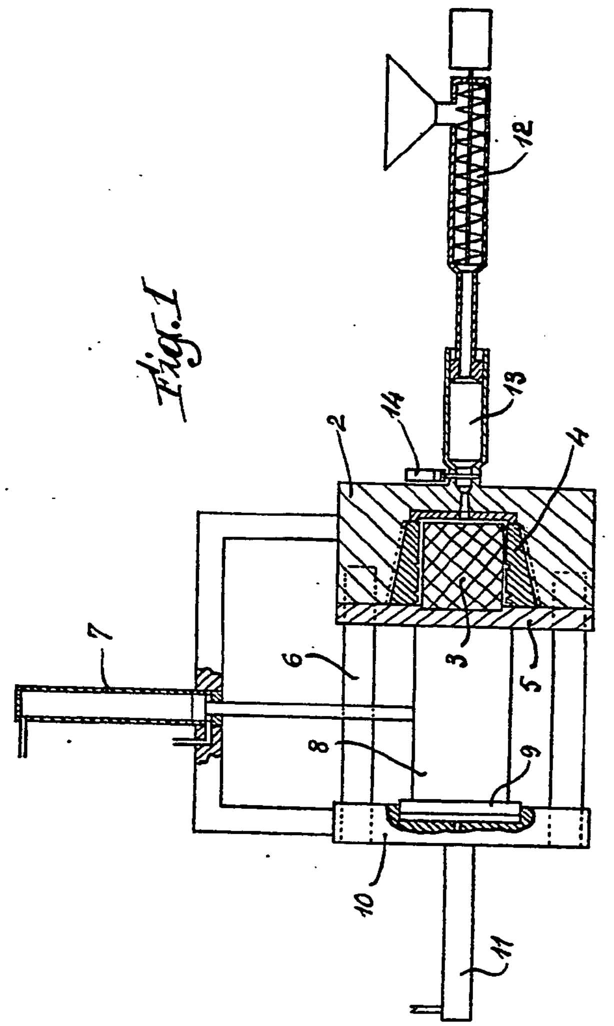

Fig. 1

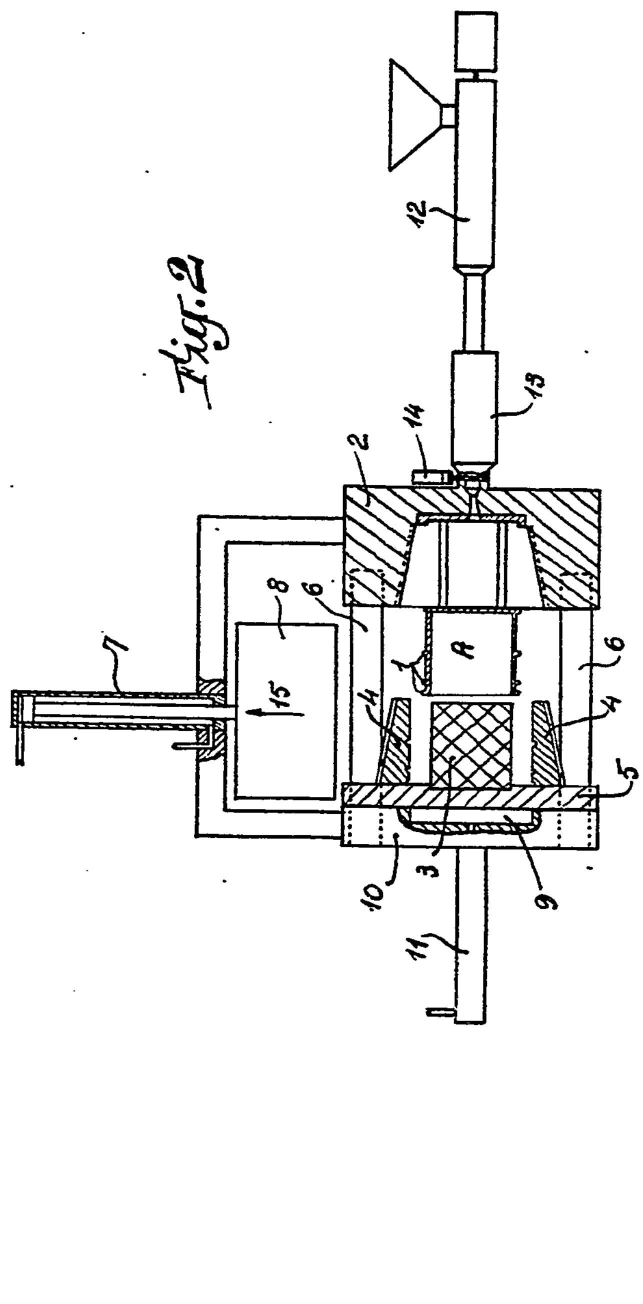

Fig.2

1160754 COMPLETE SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

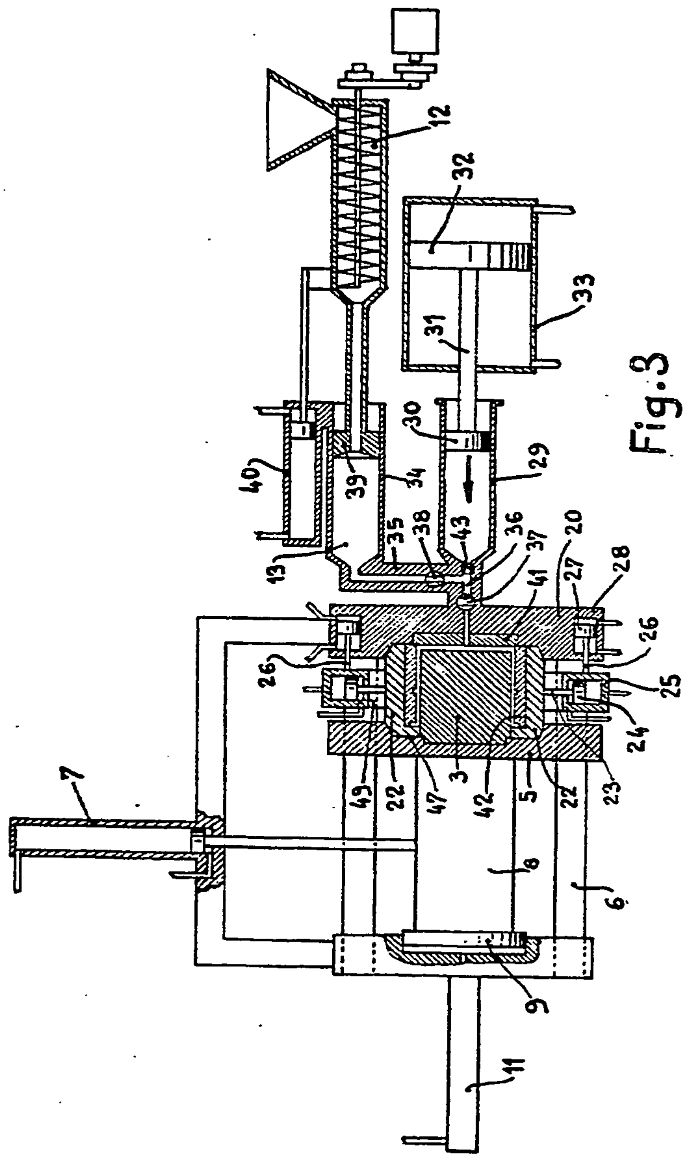

Fig.3

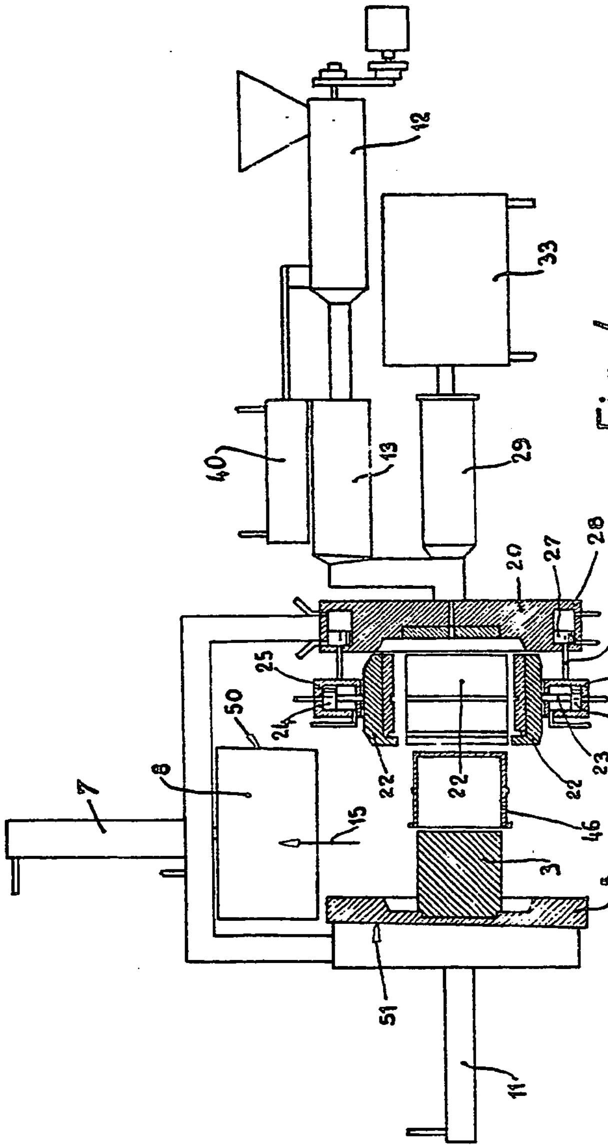
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Fig. 4

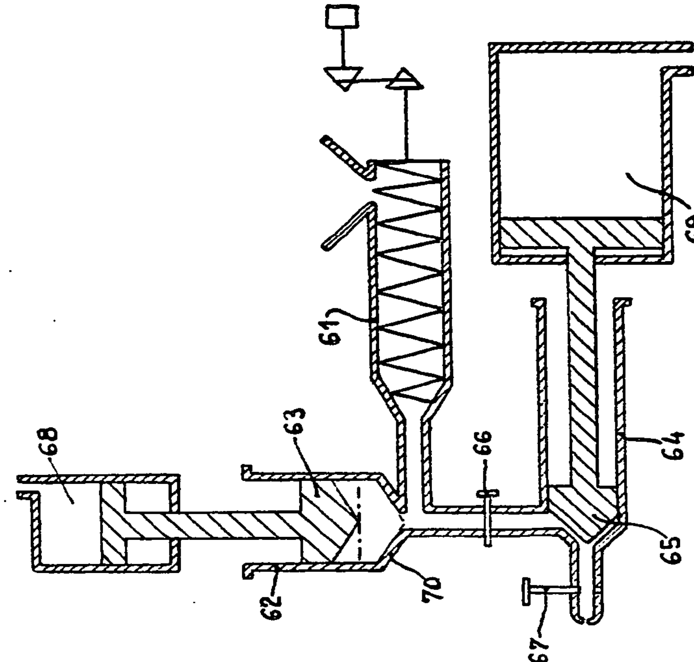
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Fig.6

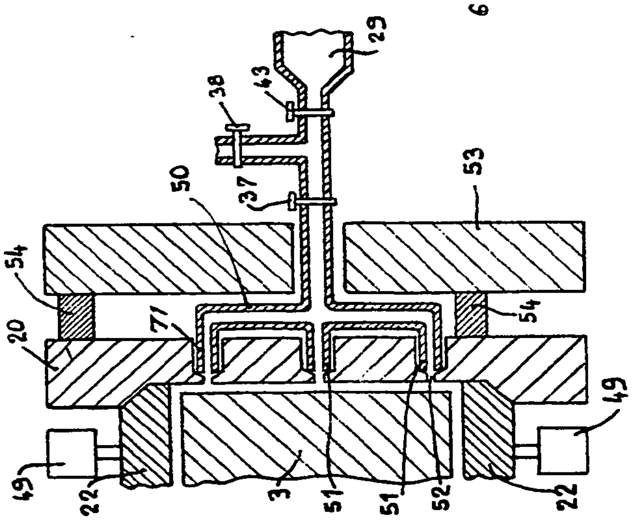
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Fig.5